Joint Tactical Radio System (JTRS) Wideband Network Waveform (WNW) Architecture Study

Phase I

Summary Briefing

Johns Hopkins University Applied Physics Laboratory (JHU/APL)

October 2002

Purpose

Provide support to JTRS WNW IPT for architecture and requirements definition

- **Develop objective Joint Information Exchange Requirements (JIER's)**
- **Propose candidate set of network architectures**
- **Provide representative operational scenario (vignettes)**
- **Create COMTEST scenario generation files describing those vignettes**

Sponsor: JTRS JPO, WNW IPT

Background

Study Structure

- **Phase I: A study effort to develop and conduct a 1st order qualitative identification of 1-3 candidate WNW network architectures and their associated primary tasks in an operational context with high level objective joint information exchange requirements and COMTEST representation**

- **Phase II: A follow-on study effort to develop three additional vignettes for modeling and simulation applications**

Leads To: *Conduct of detailed technical assessments of candidate architectures to further quantify WNW network requirements.*

Approach

- **Top-down**
  - Derive requirements from MNS, ORD, FDD, and operational documentation
  - Consider relevant studies as applicable
  - Joint Scenario provides context
- **Bottom-up**
  - Select embedded vignette and decompose
  - Examine node information flow requirements
  - Provide statistical analysis of network traffic

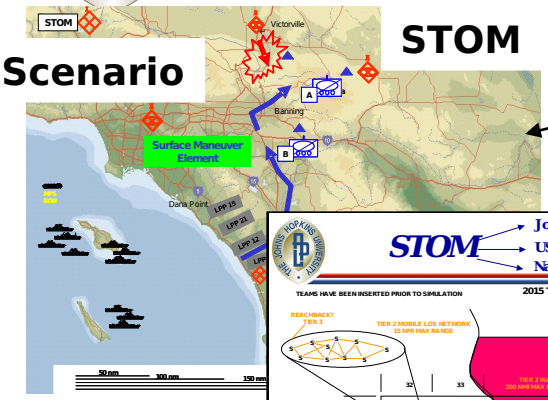
Deliverables

- **Phase I:**
  - **Joint Scenario # 1**
  - **Joint Vignette**
  - **(WNW Objective) Joint Information Exchange Requirements**
  - **COMTEST files (SDF/MDF/PDEF) for joint vignette.**
  - **Network Traffic Characterization**
  - **1-3 candidate WNW network architectures with associated qualitative assessment**
  - **Interim Report**

- **Phase II:**
  - **Selected technical studies addressing system and associated interfaces for WNW network architecture candidates.**
  - **COMTEST vignettes for USMC(2) and USN**

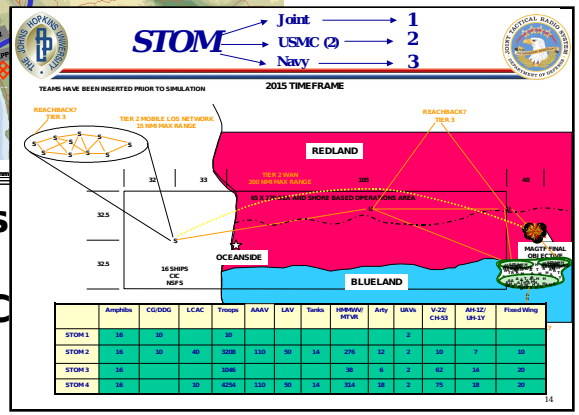
Methodology Overview

Scenario



STOM

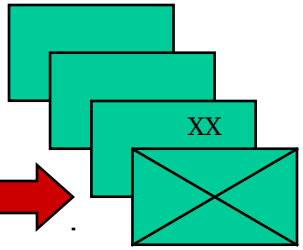
Operational Context



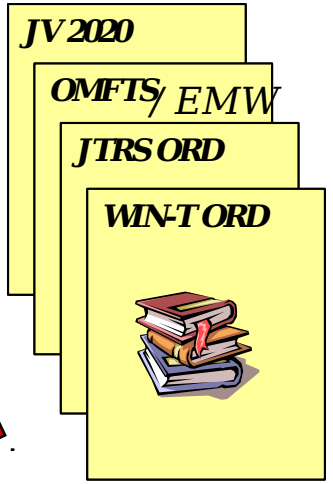
Vignettes

- Joint
- USMC
- USN

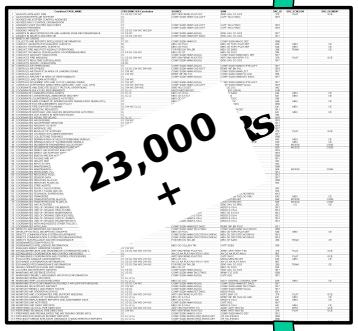
2018 C2 Architecture



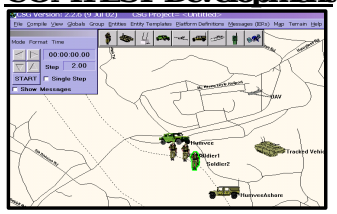
Functionality Crosswalk



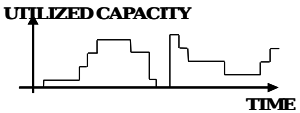
Marine/JIER Functional Mapping ~250

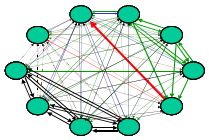


COMTEST Development

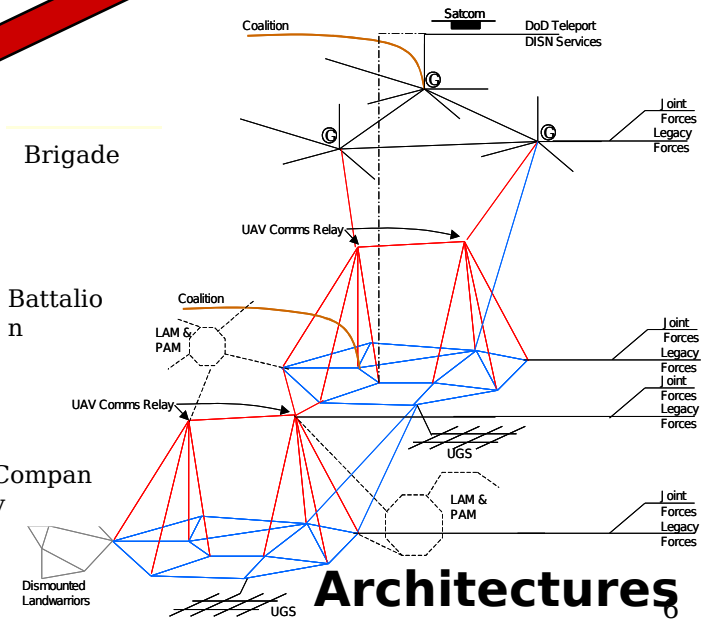


Traffic Characterization

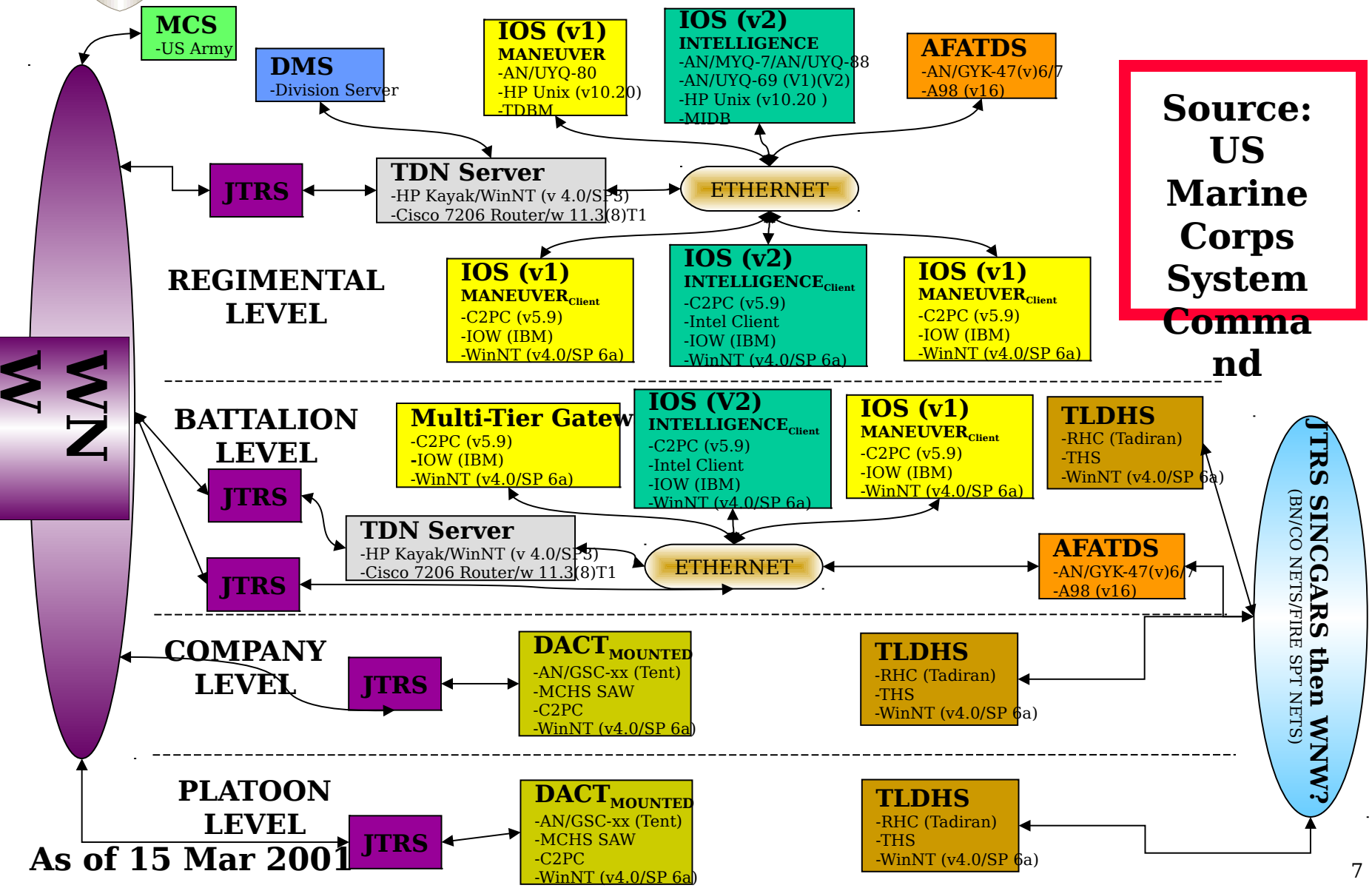




Architectures

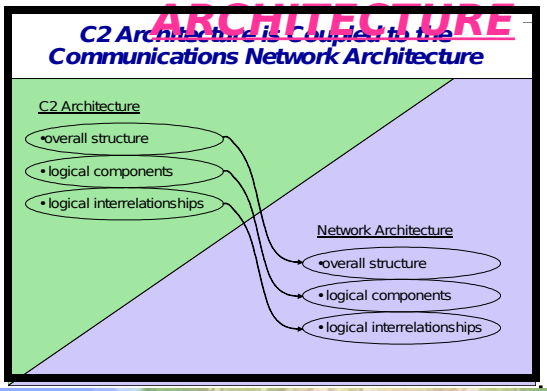


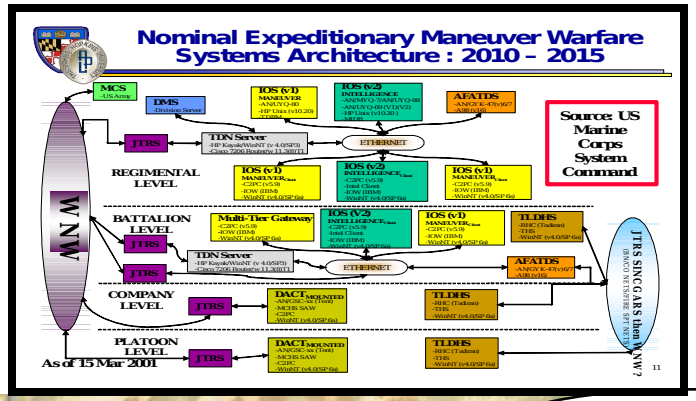
Nominal Expeditionary Maneuver Warfare Systems (C2) Architecture : ~2018



JTRS (WNW) in the C2 Architecture

JTRS NODE Information Flow Based Upon Anticipated 2018 C2 ARCHITECTURE





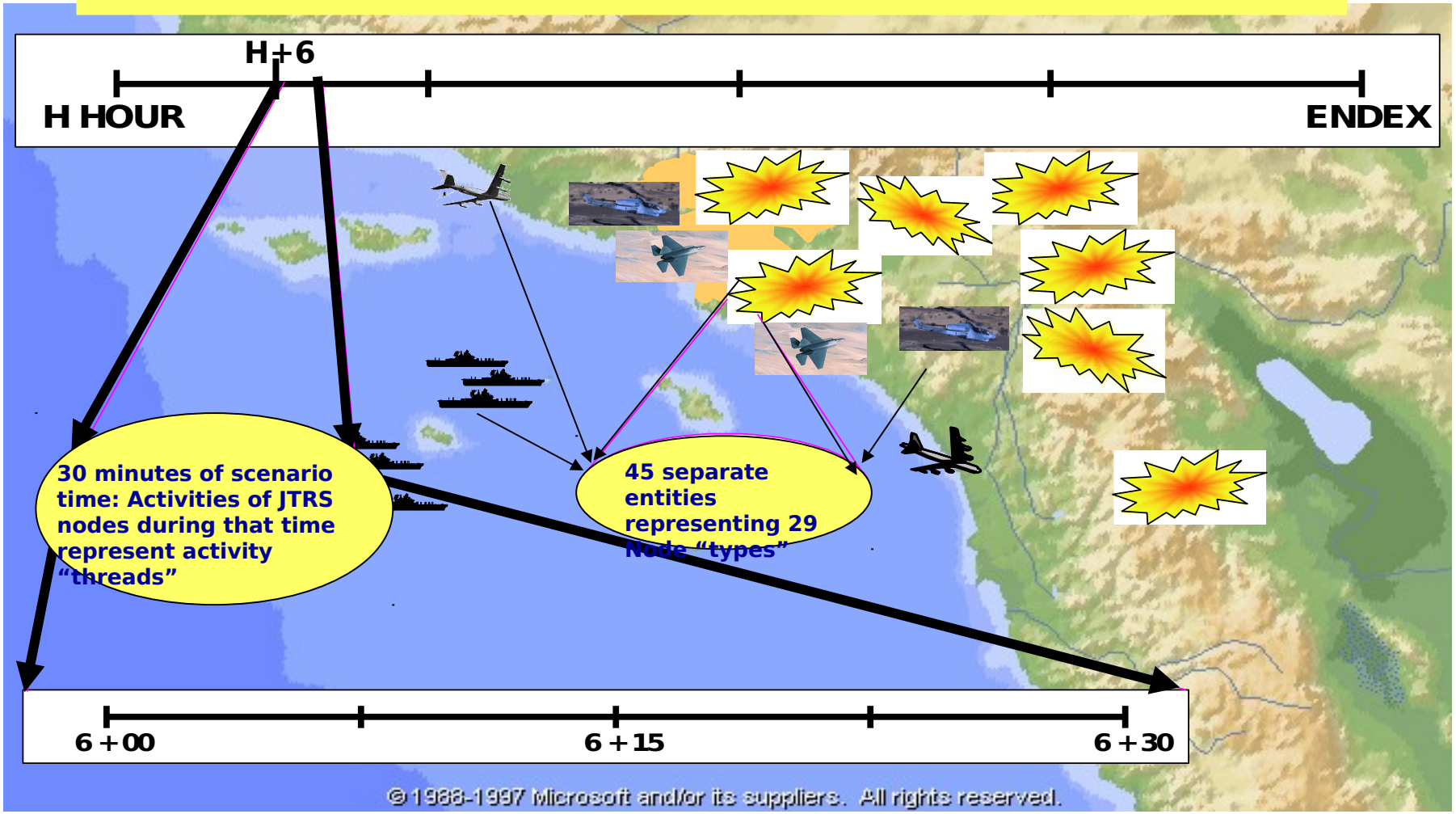
Joint Scenario #1

Olympic Dragon 04

Original Slide
From MCWL

JS# 1 Vignette

Vignette represents 30 minutes of total scenario time: H+6 to H+6.5



Summary of JTRS Node Types (29)

Maneuver
- MEU CO
- BN CDR
- BN FSCC
- SACC
- CO CDR
- CO FO/FAC
- DDG
- ARTY

Tilt Rotor and Helicopter
- LHD HDC
- AH-1W CAS
- AH-1W CONVOY ESCORT
- C22/CH-53 RESUPPLY
- V22 TROOP INSERTION
- V22 MEDEVAC

Fixed Wing
- TACC
- AAW
- REFUELER
- E-2C
- UAV
- JSTARS
- F/A-18 STRIKE
- F/A-18 CAS
- FAC-A

Logistic
- LPD TAC LOG
- LSD SUPPLY SHIP
- LCAC
- FARP
- CONVOY
- LPD CSSE

Other Node Types
- COALITION
- REACHBACK
- CMOC

OTHER FORCE NODES (3) INCLUDED FOR TRAFFIC CHARACTERIZATION ONLY

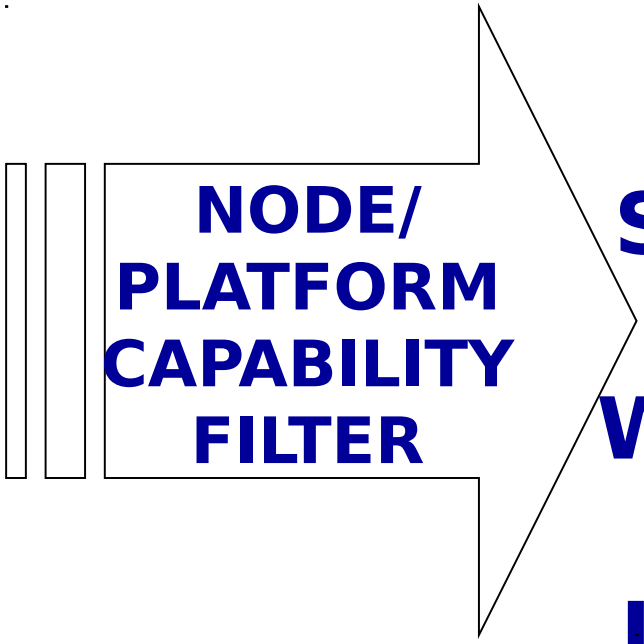
© 1988-1999 Microsoft and/or its suppliers. All rights reserved.

Node/ Platform Capability Filtering Process Categorizes JTRS Node Types into Objective Functionalities

Summary of J TRS Node Types

Maneuver	Tilt Rotor and Helicopter	Fixed Wing	Logistic
MEU CO	LHD HDC	TACC	LPD TAC LOG
BN CDR	AH-1W CAS	AAW	LSD SUPPLY SHIP
BN FSCC	AH-1W CONVOY ESCORT	REFUELER	LCAC
SACC	C22/CH-53 RESUPPLY	E-2C	FARP
CO CDR	V22 TROOP INSERTION	UAV	CONVOY
CO FO/FAC	V22 MEDEVAC	J STARS	LPD CSSE
DDG		F/A-18 STRIKE	
ARTY		F/A-18 CAS	
		FAC-A	

37



C2

SENSORS

WEAPONS

LOGISTIC

Table of JTRS Node Functionality Categories

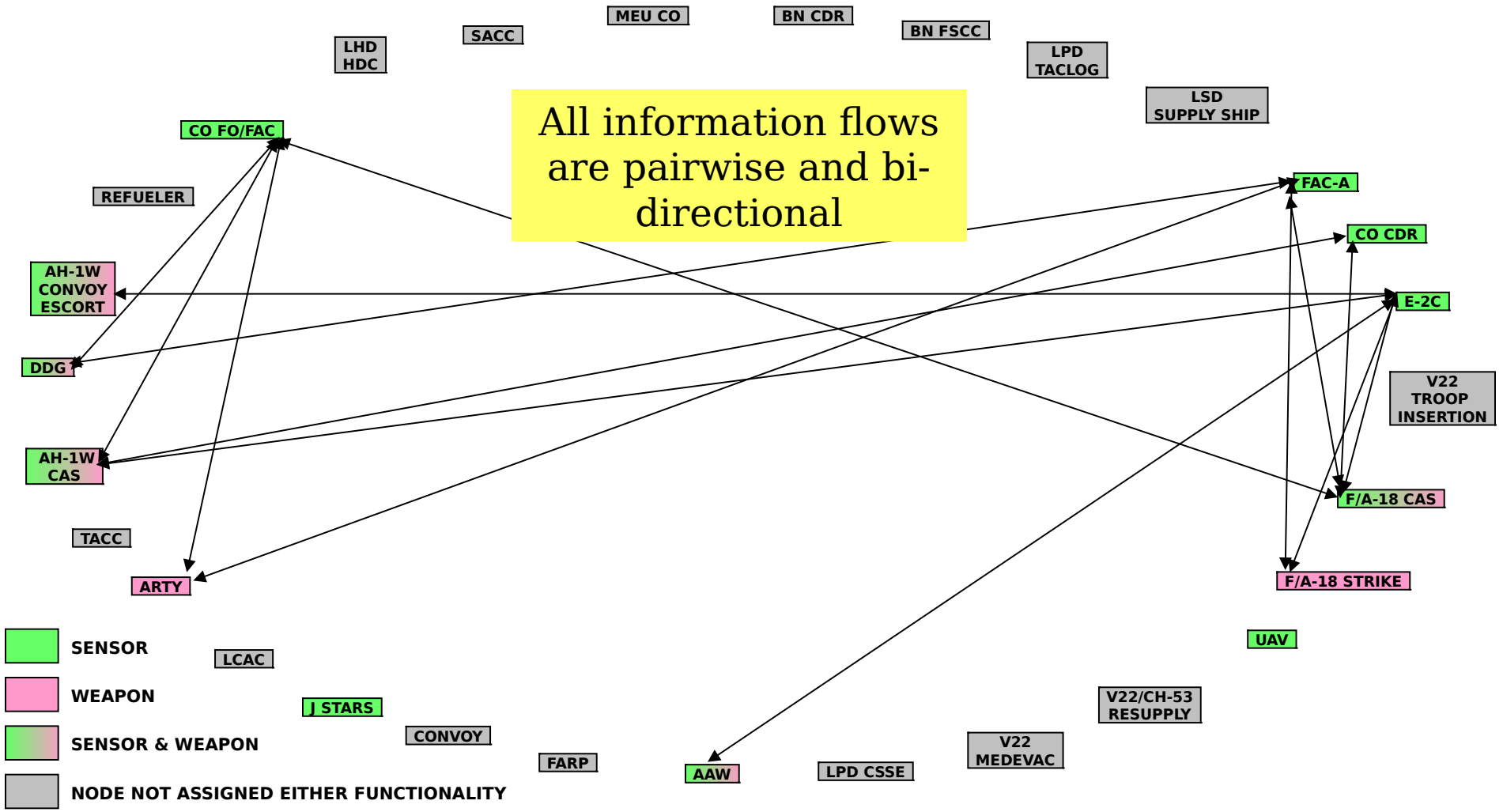
Some JTRS Node Types possess more than one Objective Functionality

J TRS NODE TYPES	FUNCTIONALITIES			
	C2	SENSOR	WEAPON	LOGISTICS
MEU CO	X			
SACC	X			
BN CDR	X			
BN FSCC	X			
CO CDR	X	X		
CO FO/FAC	X	X		
ARTY			X	
LPD - CSSE	X			X
LHD - HDC	X			
V22 - TROOP INSERTION				X
V22/CH-53 - RESUPPLY				X
V-22 - MEDEVAC				X
AH-1W - CAS		X	X	
AH-1W CONVOY ESCORT		X	X	
LPD - TACLOG	X			X
LSD - SUPPLY SHIP	X			X
FARP				X
TACC	X			
DDG		X	X	
REFUELER				X
J STARS		X		
E-2C	X	X		
UAV		X		
AAW		X	X	
F/A-18 STRIKE			X	
F/A-18 CAS		X	X	
FAC-A	X	X		
CONVOY				X
LCAC				X

Functionality assignments can be adjusted and modification incorporated into JIER Building Process.

Example Information Flow Pairing

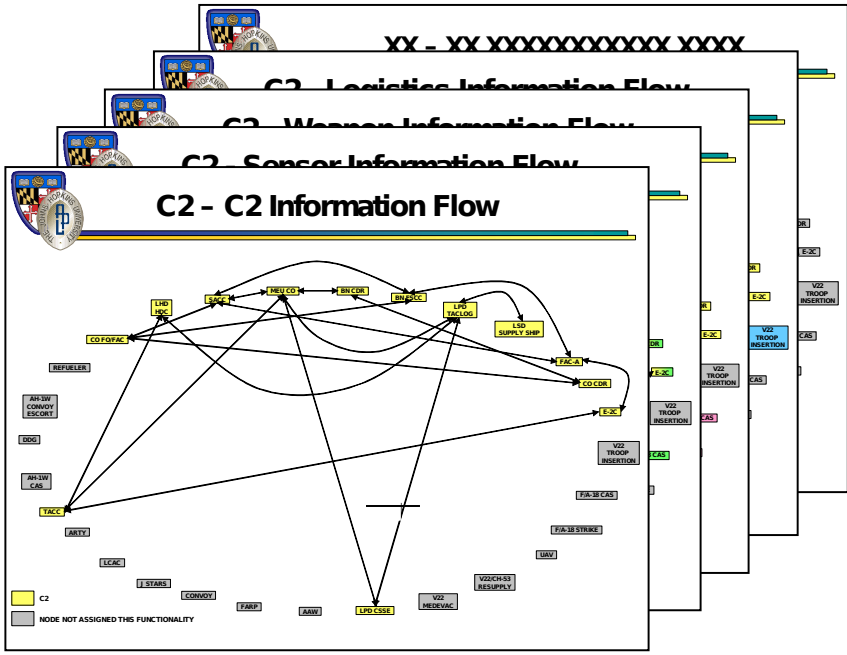
Sensor - Weapon

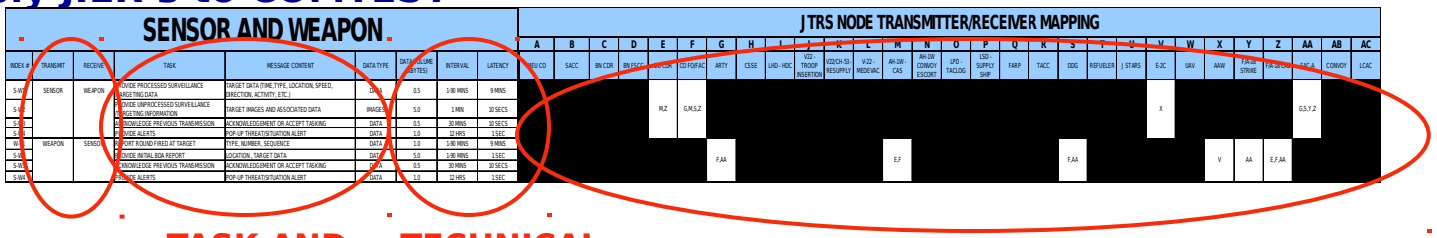


Subjective information flow pairing adjustments easily incorporated into JIER building process.

JIER Building Process

- **Identify Objective Functionalities for each JTRS Node Type**
- **Determine Information Flow between JTRS Node Types**
- **For each Objective Functionality Pairing, compose the list of JIER tasks and messages**
- **Validate technical parameters**
- **For each JIER, add the list of transmitter/ receiver pairings**
- **Apply JIER's to COMTEST**





INFORMATION FLOW PAIRING

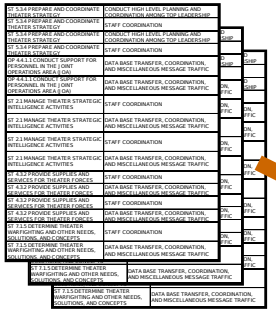
TASK AND MESSAGE LIST

TECHNICAL PARAMETERS

TRANSMITTER/RECEIVER PAIRINGS

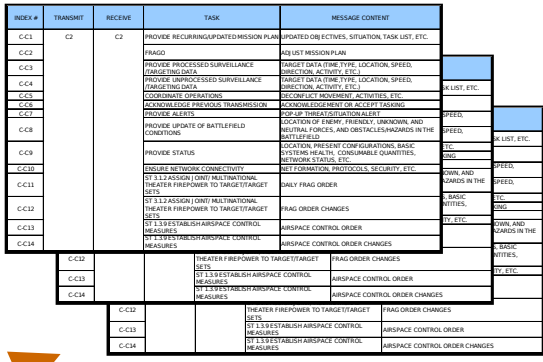
JIERs possess a robust pedigree from multiple sources and previous studies

Baseline Task and Message Lineage

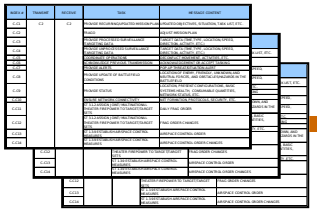


LOGISTIC UJTL

USMC - SEP 2002

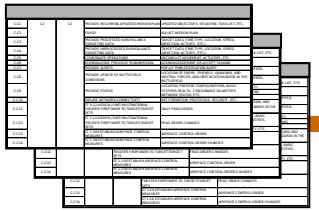


ASA/ALT - MAY 2001



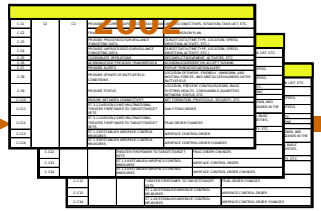
FCS NETWORK-CENTRIC CONCEPTS AND OPERATIONS STUDY PHASE I

ASA/ALT - FEB 2002



FCS NETWORK-CENTRIC CONCEPTS AND OPERATIONS STUDY PHASE II

DARPA/CECOM - MAY 2002

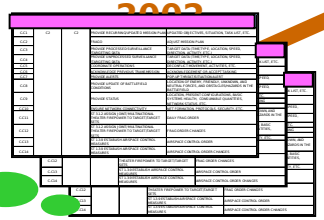


FCS C2 EXPERIMENT

JTRS WNW BASELINE TASK AND MESSAGE LIST

IER SET ADAPTED BY PI WIN-T/MILSATCOM FOR ARCHITECTURE DESIGN

CECOM/MITRE - AUG 2002

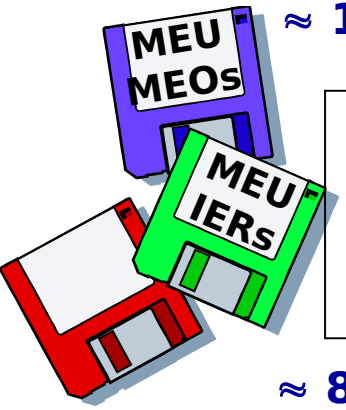


FCS C4ISR U OF A ARCHITECTURE STUDY

- NETWORK CENTRIC FOCUSED
- ENGINEERING LEVEL CLASS OF TASKS AND MESSAGES
- JOINT BASED

Incorporating USMC IER'S

23,000+ IER Lists Were Condensed Into a Smaller List



≈ 15,000 IERs

- Remove below company level
- Remove duplicate tasks
- Combine similar tasks
- Removed non-applicable tasks
- Eliminate discrete hierarchies

≈ 8,000 IERs

Condensed list comprises major USMC operational tasks

Validation Process Results in Condensed USMC IER List Embedded Within the Baseline Task List

C2 AND C2

INDEX #	TRANSMIT	RECEIVE	TASK	MESSAGE CONTENT
C-C1	C2	C2	PROVIDE RECURRING/UPDATED MISSION PLAN	UPDATED OBJECTIVES, SITUATION, TASK LIST, ETC.
C-C2			FRAGO	ADJUST MISSION PLAN
C-C3			PROVIDE PROCESSED SURVEILLANCE /TARGETING DATA	TARGET DATA (TIME,TYPE, LOCATION, SPEED, DIRECTION, ACTIVITY, ETC.)
C-C4			PROVIDE UNPROCESSED SURVEILLANCE /TARGETING DATA	TARGET DATA (TIME,TYPE, LOCATION, SPEED, DIRECTION, ACTIVITY, ETC.)
C-C5			COORDINATE OPERATIONS	DECONFLICT MOVEMENT, ACTIVITIES, ETC.
C-C6			ACKNOWLEDGE PREVIOUS TRANSMISSION	ACKNOWLEDGEMENT OR ACCEPT TASKING
C-C7			PROVIDE ALERTS	POP-UP THREAT/SITUATION ALERT
C-C8			PROVIDE UPDATE OF BATTLEFIELD CONDITIONS	LOCATION OF ENEMY, FRIENDLY, UNKNOWN, AND NEUTRAL FORCES, AND OBSTACLES/HAZARDS IN THE BATTLEFIELD

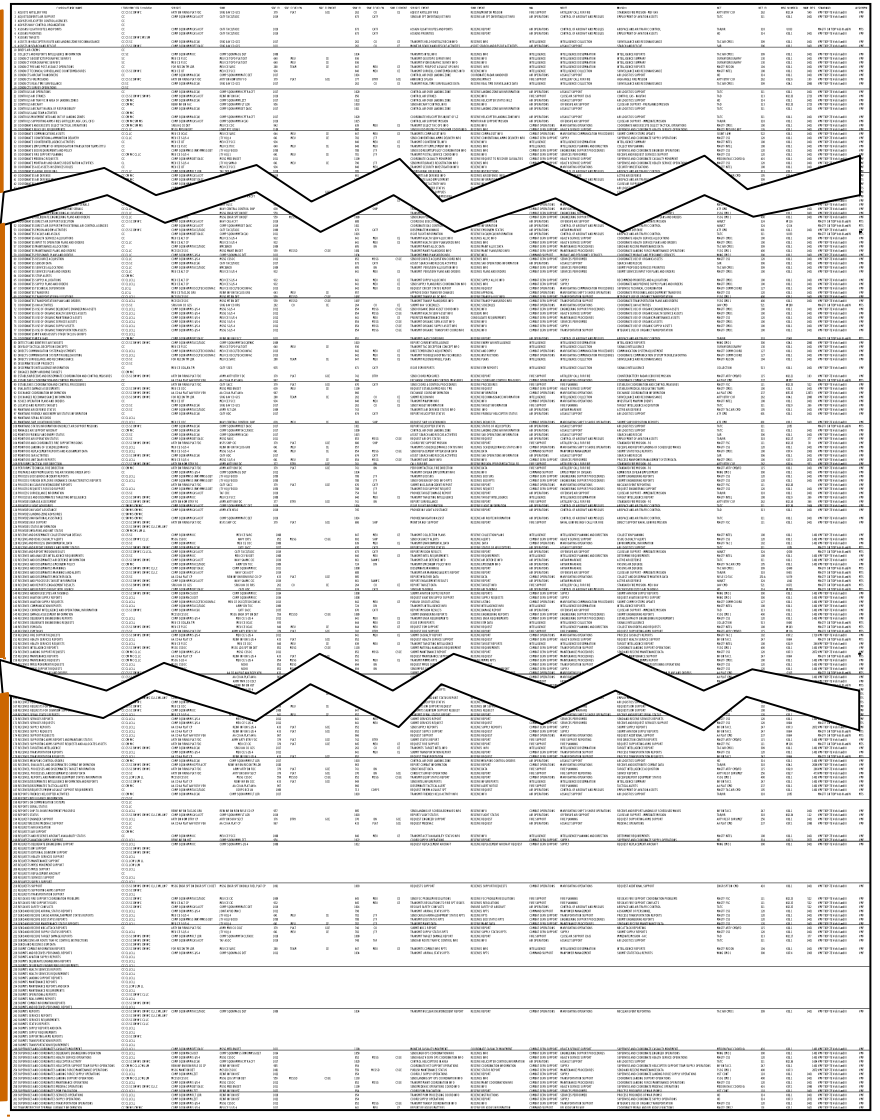
C2 AND SENSOR

INDEX #	TRANSMIT	RECEIVE	TASK	MESSAGE CONTENT
C-S1	C2	SENSOR	PROVIDE RECURRING/UPDATED MISSION PLAN	UPDATED OBJECTIVES, SITUATION, TASK LIST, ETC.
C-S2			FRAGO	ADJUST MISSION PLAN
C-S3			COORDINATE OPERATIONS	DECONFLICT MOVEMENT, ACTIVITIES, ETC.
C-S4			REQUEST SENSOR/SURVEILLANCE COVERAGE	SENSOR TYPE, AREA, TIME, ETC.
C-S5			REQUEST MOVEMENT	LOCATION, DIRECTION, SPEED, OBSTACLES, REPORTING POINTS, ETC.
C-S6			REQUEST CONFIGURATION CHANGE	SYSTEM/PLATFORM SETTINGS
C-S7			ACKNOWLEDGE PREVIOUS TRANSMISSION	ACKNOWLEDGEMENT OR ACCEPT TASKING
C-S8			PROVIDE ALERTS	POP-UP THREAT/SITUATION ALERT
C-S9			PROVIDE UPDATE OF BATTLEFIELD CONDITIONS	LOCATION OF ENEMY, FRIENDLY, UNKNOWN, AND NEUTRAL FORCES, AND OBSTACLES/HAZARDS IN THE BATTLEFIELD
C-S10			ENSURE NETWORK CONNECTIVITY	NET FORMATION, PROTOCOLS, SECURITY, ETC.
S-C1	SENSOR	C2	PROVIDE PROCESSED SURVEILLANCE /TARGETING DATA	TARGET DATA (TIME,TYPE, LOCATION, SPEED, DIRECTION, ACTIVITY, ETC.)
S-C2			PROVIDE UNPROCESSED SURVEILLANCE /TARGETING INFORMATION	TARGET IMAGES AND ASSOCIATED DATA
S-C3			ACKNOWLEDGE PREVIOUS TRANSMISSION	ACKNOWLEDGEMENT OR ACCEPT TASKING
S-C4			PROVIDE ALERTS	POP-UP THREAT/SITUATION ALERT
S-C5			PROVIDE STATUS	LOCATION, PRESENT CONFIGURATIONS, BASIC SYSTEMS HEALTH, CONSUMABLE QUANTITIES, NETWORK STATUS, ETC.
S-C6			ST 2.2 COLLECT THEATER STRATEGIC INFORMATION (JSTARS)	SAR
S-C7			ST 2.2 COLLECT THEATER STRATEGIC INFORMATION (JSTARS)	MTI
S-C8			ST 2.2 COLLECT THEATER STRATEGIC INFORMATION (UAV)	SAR

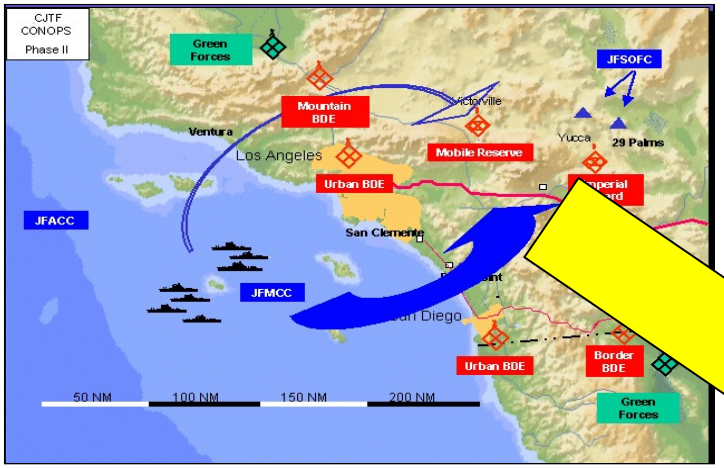
C2 AND WEAPON

INDEX #	TRANSMIT	RECEIVE	TASK	MESSAGE CONTENT
C-W1	C2	WEAPON	PROVIDE RECURRING/UPDATED MISSION PLAN	UPDATED OBJECTIVES, SITUATION, TASK LIST, ETC.
C-W2			FRAGO	ADJUST MISSION PLAN INCLUDING MID COURSE CORRECTIONS TO FLIGHT PATH FOR LAM/PAM/USAF
C-W3			COORDINATE OPERATIONS	DECONFLICT MOVEMENT, ACTIVITIES, ETC.
C-W4			REQUEST THREAT ENGAGEMENT	TARGET TYPE, LOCATION, SPEED, ALTITUDE, ETC.
C-W5			REQUEST MOVEMENT	LOCATION, DIRECTION, SPEED, OBSTACLES, REPORTING POINTS, ETC.
C-W6			REQUEST CONFIGURATION CHANGE	SYSTEM/PLATFORM SETTINGS
C-W7			ACKNOWLEDGE PREVIOUS TRANSMISSION	ACKNOWLEDGEMENT OR ACCEPT TASKING
C-W8			PROVIDE ALERTS	POP-UP THREAT/SITUATION ALERT
C-W9			PROVIDE UPDATE OF BATTLEFIELD CONDITIONS	LOCATION OF ENEMY, FRIENDLY, UNKNOWN, AND NEUTRAL FORCES, AND OBSTACLES/HAZARDS IN THE BATTLEFIELD
C-W10			ENSURE NETWORK CONNECTIVITY	NET FORMATION, PROTOCOLS, SECURITY, ETC.
C-W11			ST 3.2 ATTACK STRATEGIC TARGET SETS (NSFS)	TARGET TYPES, LOCATIONS, TIMES, ETC
C-W12			ST 3.2 ATTACK STRATEGIC TARGET SETS	NSFS COORDINATION
W-C1	WEAPON	C2	REPORT ROUND FIRED AT TARGET	TYPE, NUMBER, SEQUENCE
W-C2			PROVIDE INITIAL BDA REPORT	LOCATION , TARGET DATA
W-C3			ACKNOWLEDGE PREVIOUS TRANSMISSION	ACKNOWLEDGEMENT OR ACCEPT TASKING
W-C4			PROVIDE ALERTS	POP-UP THREAT/SITUATION ALERT
W-C5			PROVIDE STATUS	LOCATION, PRESENT CONFIGURATIONS, BASIC SYSTEMS HEALTH, CONSUMABLE QUANTITIES, NETWORK STATUS, ETC.
W-C6			ST 3.2 ATTACK STRATEGIC TARGET SETS	NSFS COORDINATION

COMPARISON BASED UPON:
- SOURCE AND DESTINATION PAIRING
- TASK DESCRIPTION INCLUSION OF
- AVIATION
- LOGISTICS

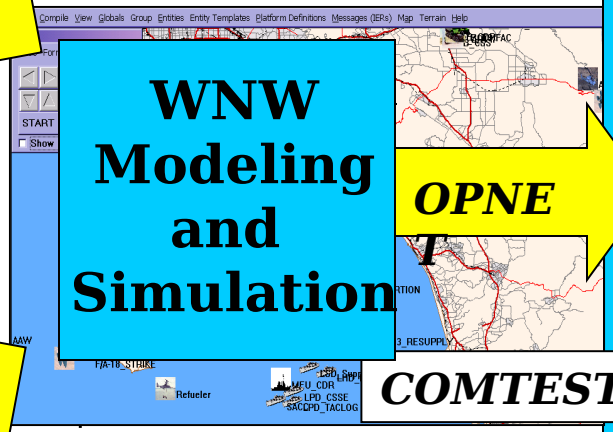


Study Inputs for Evaluating Network Performance



Scenario

Describes Physical Node Placement



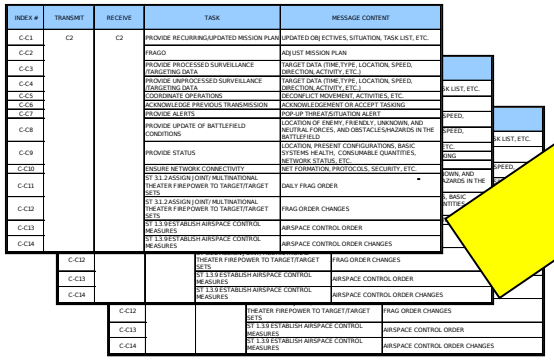
WNW Modeling and Simulation

OPNET

COMTEST

JTRS WNW Network Performance

JTRS WNW Traffic Characterization



INDEX #	TRANSMIT	RECEIVE	TASK	MESSAGE CONTENT
C-C1	C2	C2	PROVIDE RECURRING/UPDATED MISSION PLAN	UPDATED OBJECTIVES, SITUATION, TASK LIST, ETC.
C-C2			FRAGO	ADJUST MISSION PLAN
C-C3			PROVIDE PROCESSED SURVEILLANCE (TARGETING DATA	TARGET DATA (TIME,TYPE, LOCATION, SPEED, DIRECTION, ACTIVITY, ETC.)
C-C4			PROVIDE UNPROCESSED SURVEILLANCE (TARGETING DATA	TARGET DATA (TIME,TYPE, LOCATION, SPEED, DIRECTION, ACTIVITY, ETC.)
C-C5			COORDINATE OPERATIONS	DECONFLICT MOVEMENT, ACTIVITIES, ETC.
C-C6			ACKNOWLEDGE PREVIOUS TRANSMISSION	ACKNOWLEDGEMENT OR ACCEPT TASKING
C-C7			PROVIDE ALERTS	POP-UP THREAT/SITUATION ALERT
C-C8			PROVIDE UPDATE OF BATTLEFIELD CONDITIONS	LOCATION OF ENEMY, FRIENDLY, UNKNOWN, AND NEUTRAL FORCES, AND OBSTACLES/HAZARDS IN THE BATTLEFIELD
C-C9			PROVIDE STATUS	LOCATION, PRESENT CONFIGURATIONS, BASIC SYSTEMS HEALTH, CONSUMABLE QUANTITIES, NETWORK STATUS, ETC.
C-C10			ENSURE NETWORK CONNECTIVITY	NET FORMATION, PROTOCOLS, SECURITY, ETC.
C-C11			ST 3.1.2 ASSIGN JOINT/ MULTINATIONAL THEATER FIREPOWER TO TARGET/TARGET SETS	DAILY FRAG ORDER
C-C12			ST 3.1.2 ASSIGN JOINT/ MULTINATIONAL THEATER FIREPOWER TO TARGET/TARGET SETS	FRAG ORDER CHANGES
C-C13			ST 1.3.9 ESTABLISH AIRSPACE CONTROL MEASURES	AIRSPACE CONTROL ORDER
C-C14			ST 1.3.9 ESTABLISH AIRSPACE CONTROL MEASURES	AIRSPACE CONTROL ORDER CHANGES

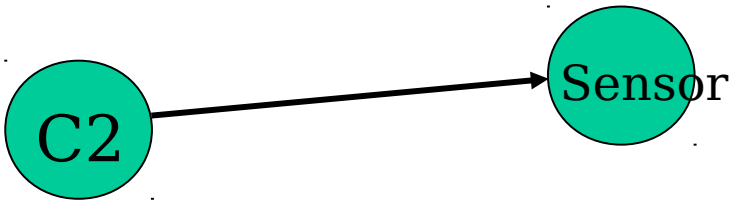
JIER's

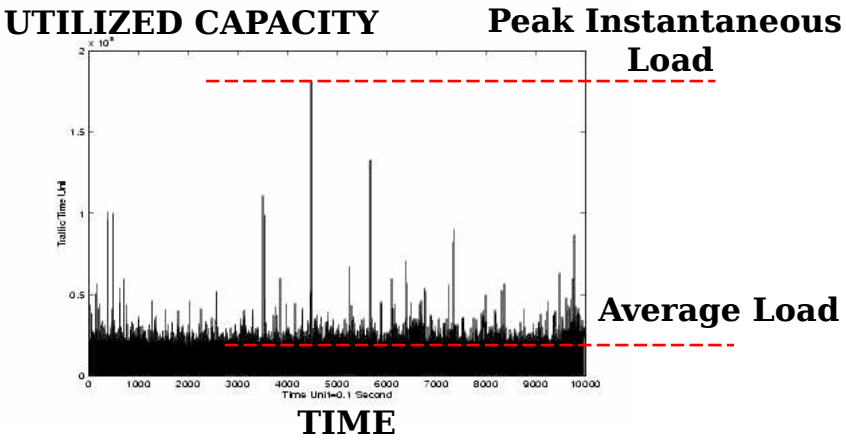
Describes Information Flow Between Nodes

Traffic Models and Characterization

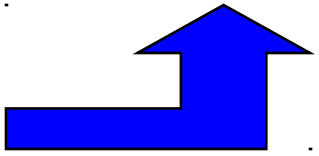
- ***JIERs provide the basis for:***
  - ***Traffic model: used in modeling/simulation***
  - ***Traffic characterization: analysis of loads; insights for communications design***

- **Loads on a physical link will be an aggregation of various message flows which is by nature stochastic**
- **Tabular methods do not completely describe but provide some characterization of "drivers"**



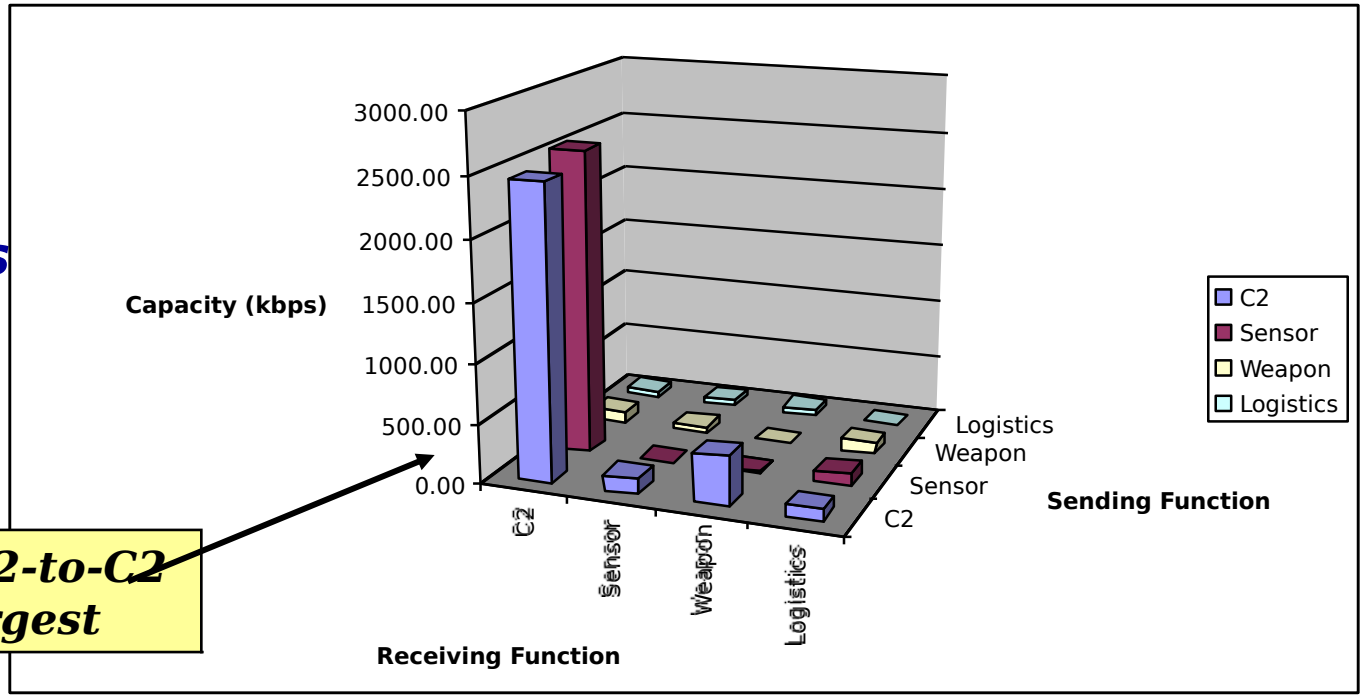


FUNCTIONS	TASK	DATA VOLUME	INTERVAL	LATENCY
C2 to Sensor	Provide Recurring/Updated Mission Plan	1 MB	720 hrs.	10 min.
C2 to Sensor	Frago	100 KB	30 min.	1 min.
C2 to Sensor	Coordinate Operations	1 MB	1 hr.	10 sec.
C2 to Sensor	Request Sensor Coverage	5 KB	1 hr.	1 sec.
⋮	⋮	⋮	⋮	⋮



Functional Capacity

Instantaneous Capacity



Sensor-to-C2 and C2-to-C2 loads are the largest

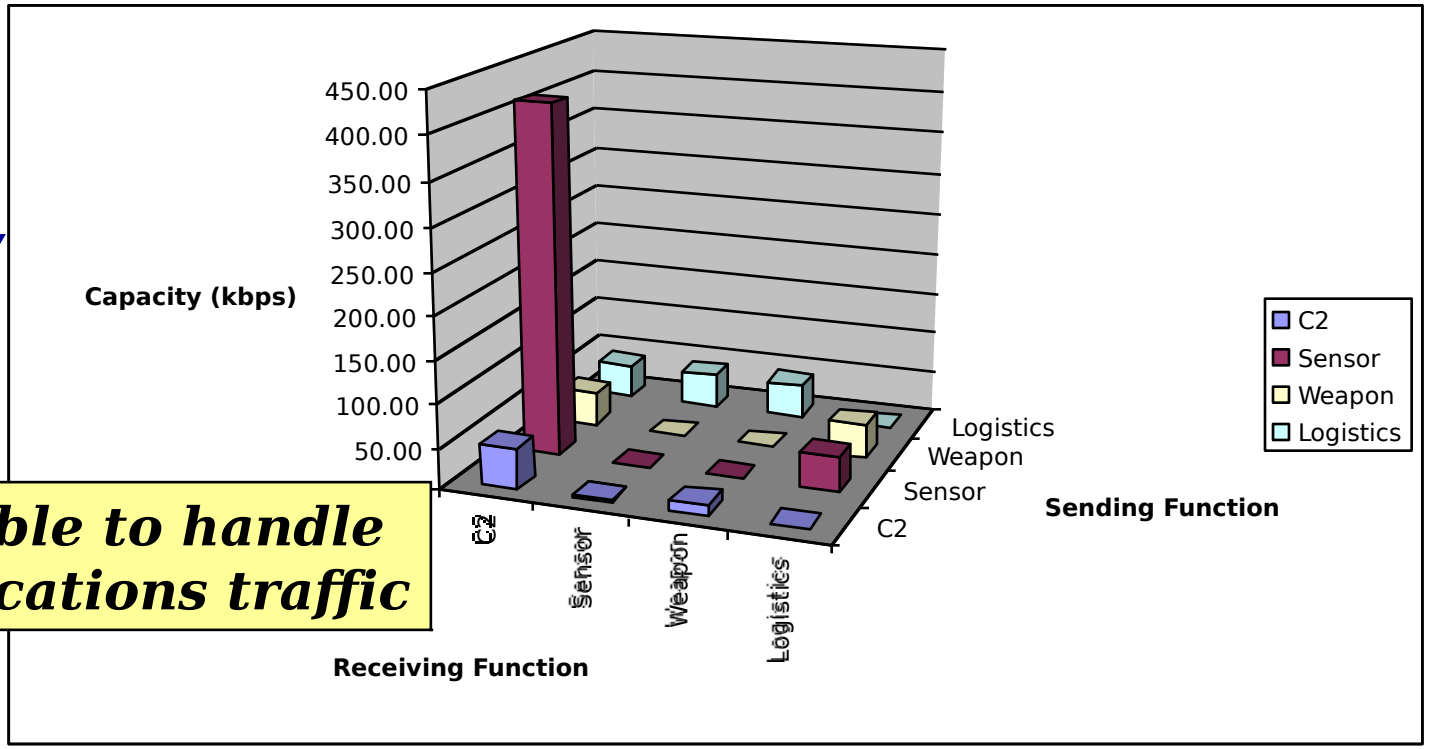
Receiving Function

Sending Function

	C2	Sensor	Weapon	Logistics
C2	2443.07	127.33	415.33	91.33
Sensor	2559.73	0.00	16.40	96.40
Weapon	96.40	56.40	0.00	96.40
Logistics	48.40	48.40	48.40	0.47

Functional Capacity

Average Capacity



VNW must be able to handle ursty communications traffic

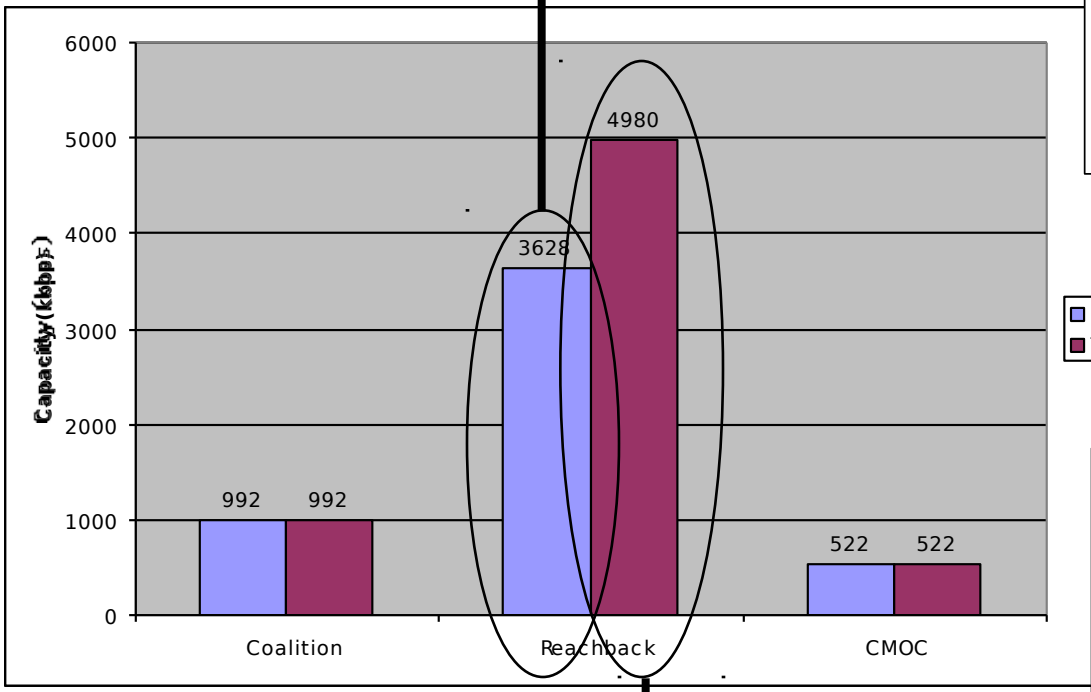
Receiving Function

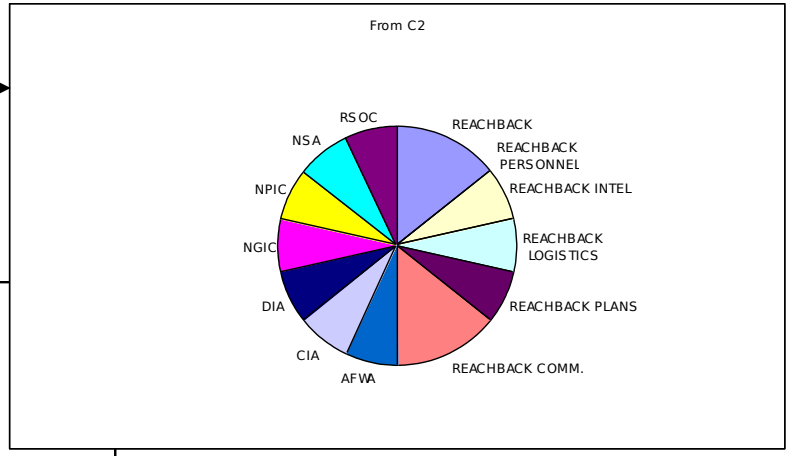
Sending Function

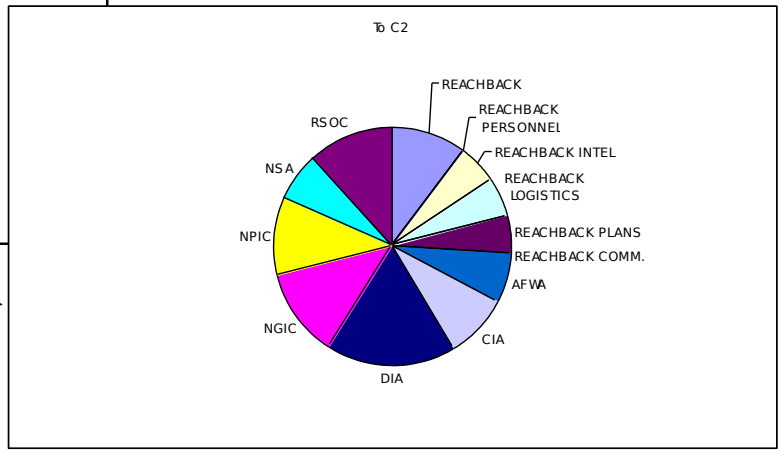
	C2	Sensor	Weapon	Logistics
C2	46.78	1.20	11.88	1.20
Sensor	413.92	0.00	0.02	40.04
Weapon	40.03	0.03	0.00	40.04
Logistics	40.00	40.00	40.00	0.08

Capacity for Coalition, Reachback, CMOC

Instantaneous Capacity



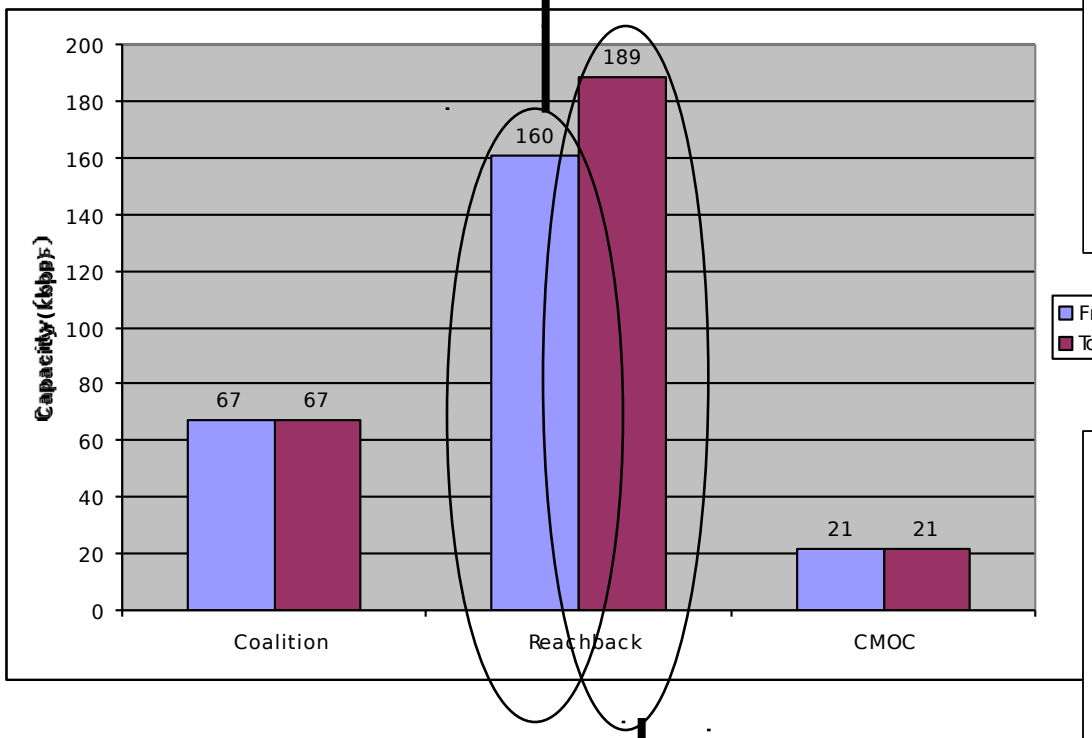


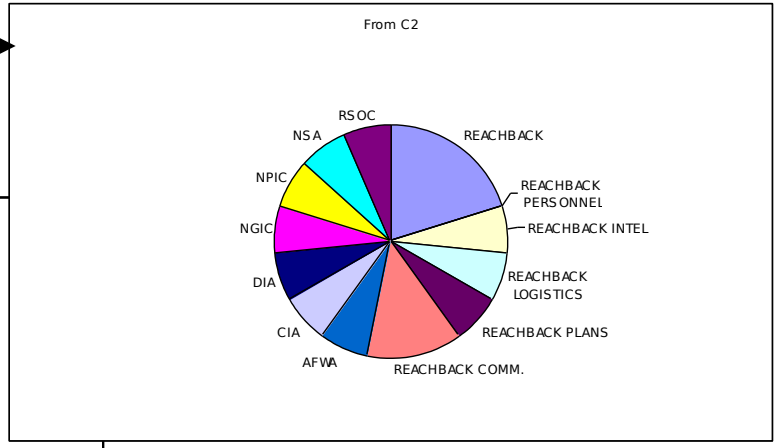


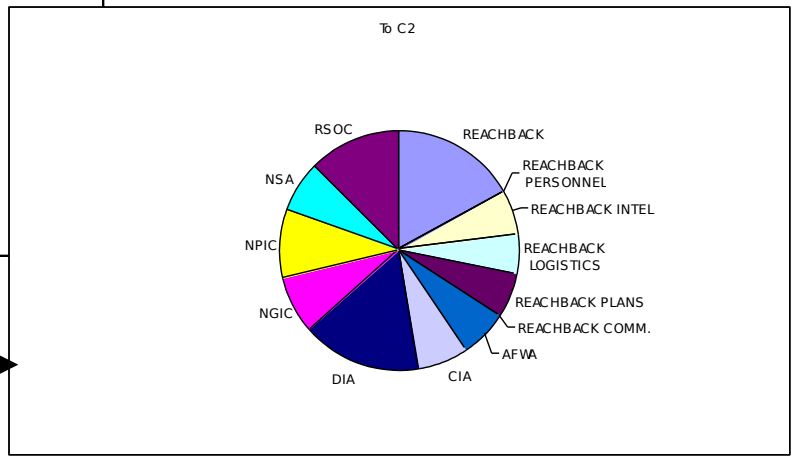
achback traffic is largest contributor and evenly distributed (to/from)

Capacity for Coalition, Reachback, CMOC

Average Capacity

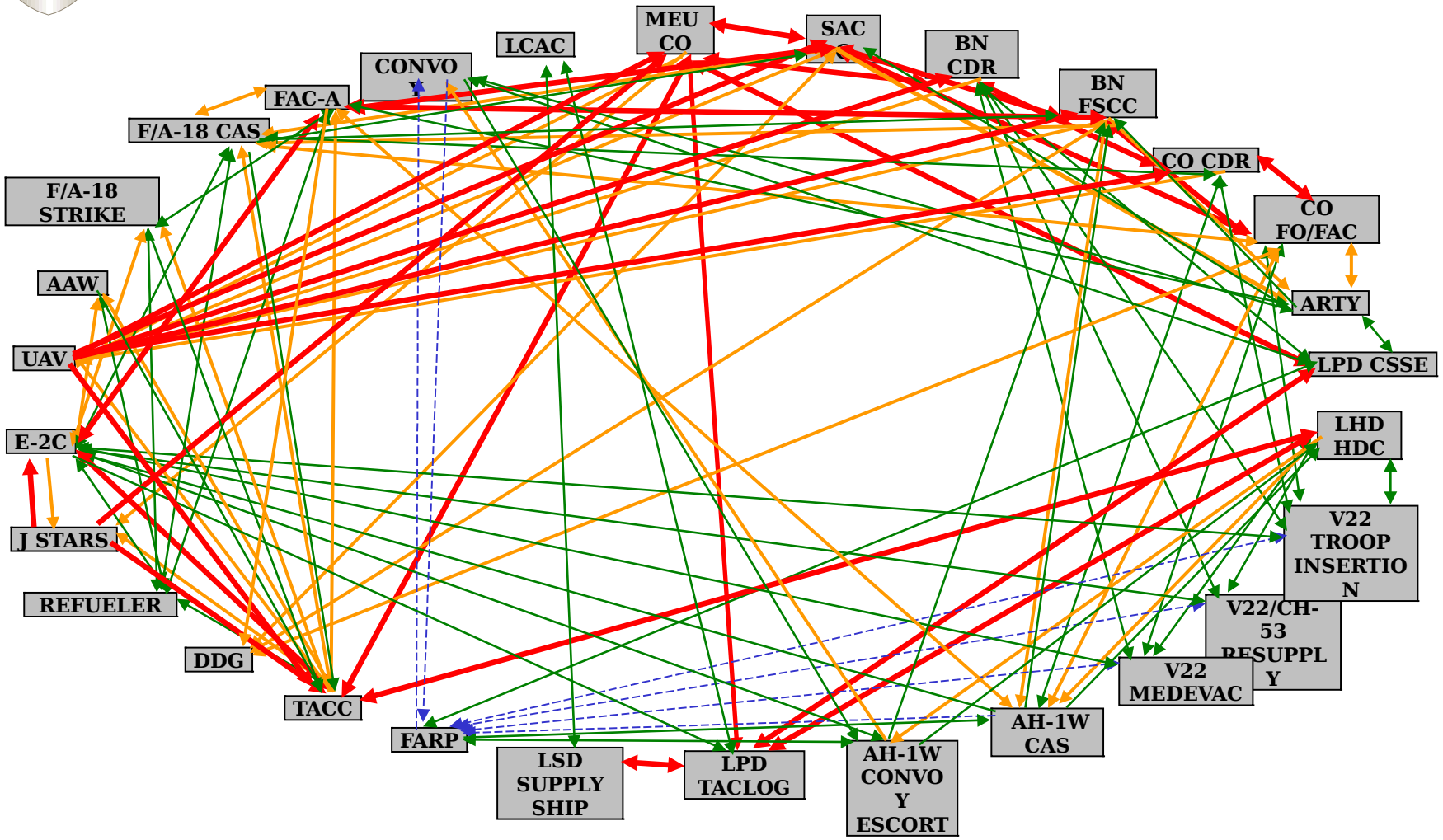






Coalition, Reachback and CMOC traffic is bursty

Worst-Case Loads Between Nodes

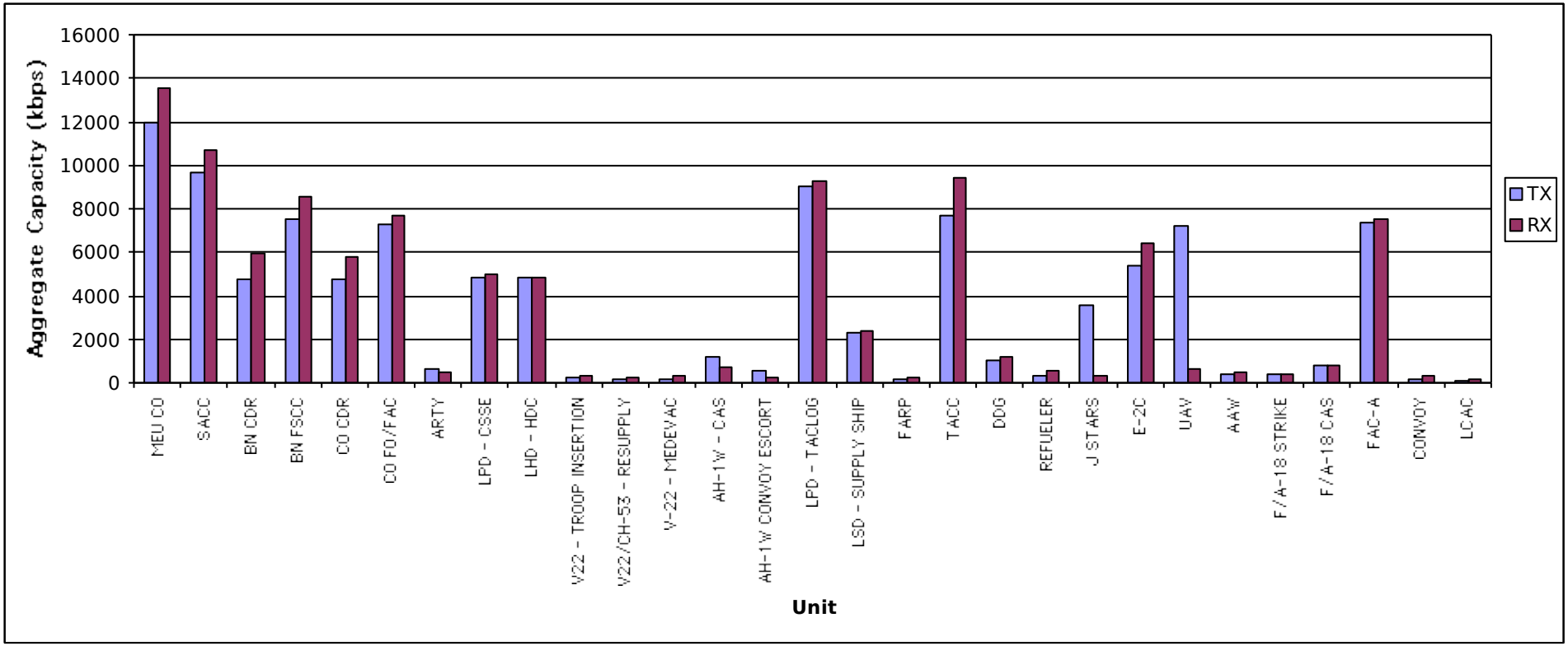


No architecture or routing implied.
End-to-end source to destination capacity requirements only.

0-10 Kbps
10-100 Kbps
100-1000 Kbps

This slide *illustrates* the complexity of the information exchange in a typical Joint

Node Capacities



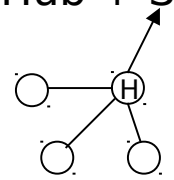
- **Grouping send/receive messages together results in large capacities for particular nodes**
  - **Multiple JTRS WNW radios potentially needed**
  - ***Note this is worst case, statistical multiplexing of traffic will lessen burden***

Possible Architecture Hierarchies

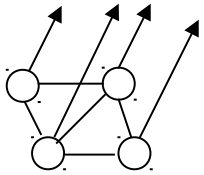
Architectural Topologies

MEU

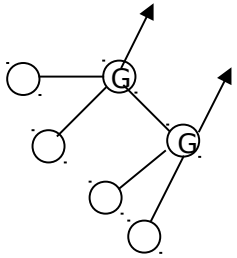
Hub + Spoke



Flat (Ad hoc)



Gateway

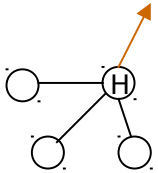


---

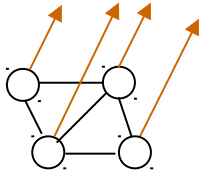
glue - connection between Bn and Co shown in brown

BN
(Inter- Plts)

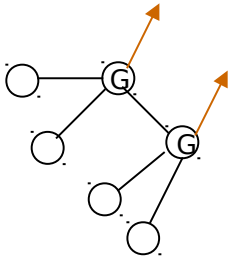
Hub + Spoke



Flat (Ad hoc)



Gateway

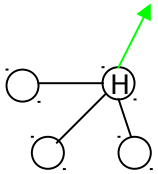


---

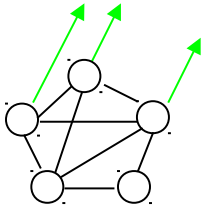
glue - connection between Plt and Co shown in green

CO
(Inter- Node)

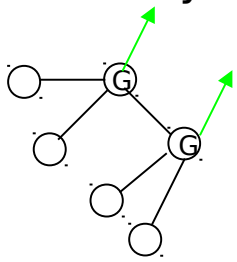
Hub + Spoke



Flat (Ad hoc)



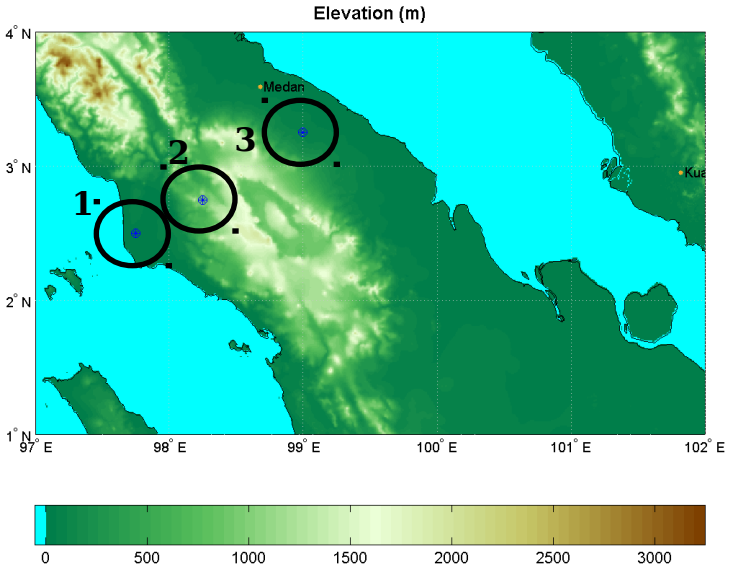
Gateway



Architectural Technolo

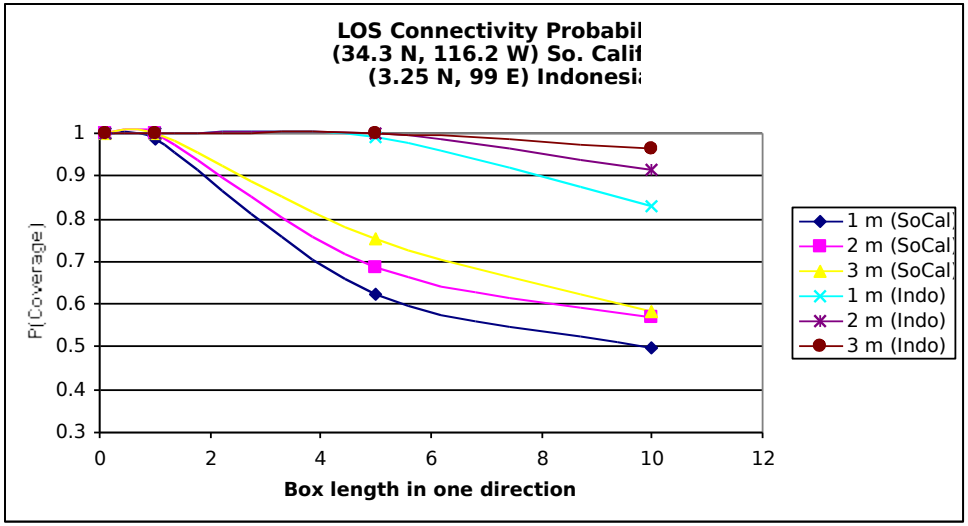
- **Communications technologies will be overlayed onto the topologies**
- **Assessed general pros/cons of architectures in Phase I**
- **Platforms will be addressed as part of technologies to determine appropriate roles**
  - **UAVs**
  - **SATCOM**
  - **other**

Typical Trade Study
(Connectivity)



- LOS connectivity only reliably achieved over very small distances
- A low flying UAV provides highly reliable LOS connectivity

- Three regions, similar to encountered in phases of OMFTS
- Ranges considered for:
  - Subregion size
  - Antenna height
  - UAV height
- Monte Carlo analysis



Summary

- **Study products are *process* and :**
  - **OD04 Scenario Vignette**
  - **JIER Set**
  - **COMTEST Files**
  - **Traffic Model results**
  - **Architecture recommendations**
- **Methodology responsive to excursion**
- **Scenario and Vignette represents an operational joint force structure view**
- **Joint Information Exchange Requirements developed to provide mechanism for quantitative, broad based architectural analysis**
- **Traffic Characterization indicates specific trends for data flow rates across 2018 architecture**
- **Candidate Architectures are qualitative but provide scoping tool for continued refinement of WNW requirements and mission needs evaluation**